Taxonomic Research and Plant Germplasm Collections

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ABSTRACT

Botanical taxonomy aims to consistently incorporate all that is known about plants into a classification system, and thereby serves as an information storage and retrieval system and provides a means of prediction and communication for all botanical sciences. Taxonomic research depends on field exploration and study of both herbarium specimens and living plant collections. The study of crop species, whose histories have been enormously complicated by domestication and cultivation, is especially dependent on germplasm collections, which provide a data base for comparative studies. For example, recent taxonomic studies of *Chenopodium* and *Citrus* germplasm collections led to breakthroughs in basic knowledge about these plants that would otherwise have been difficult if not impossible to attain, and these advances will have important effects on agricultural research. Index terms: botany, *Chenopodium* spp., *Citrus* spp., herbarium specimens, plant exploration, plant germplasm collections, systematics, taxonomy (botanical).

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Taxonomic Research and Plant Germplasm Collections

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Taxonomy and its uses

"The world is so full of a number of things . . . ," in the words of Robert Louis Stevenson, and these things are very different from one another. Anyone who works with plant germplasm collections should have a keen appreciation of the manifold nature of such variability. It may be said that the task of science is to bring order to apparent disorder—whether in the physical sciences (such as ordering the kinds of elementary particles or understanding the evolution of stars and galaxies) or in the biological sciences, where one may be concerned with the orderliness of processes (such as photosynthesis, phytochrome dynamics, or DNA replication), or with the diversity of the kinds of organisms that exist. Bringing order to our understanding of the kinds of organisms that exist is the special province of taxonomy. In common with other sciences, taxonomic research is pursued in the belief that nature is inherently orderly, and the taxonomist's task is to discover the basis of that order and to find means of communicating it.

Simply put, taxonomy is *good* classification. What do I mean by good classification? It is the ordering of organisms in such a way that what is known about them is consistently incorporated into the classification. A good classification of a plant genus, say, into subgenera and sections or a species into subspecies or biotypes will integrate as much knowledge—morphologic, geographic, cytogenetic, physiologic, biochemical, whatever—about the taxa in these groups as possible. A good classification is the best information storage and retrieval system there is.

Since the goal of classification is to incorporate all available information, one may assume that not-yet-available information will fit into the classification system in an orderly, that is, predictable fashion. Thus, a good classification will suggest to plant breeders, for example, where certain traits, such as disease resistance, might be sought, or where genetic barriers to hybridization (or lack of them) might be expected, or where levels of heterosis might be maximized.

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In classifying plants, taxonomy serves the incidental function of naming the units that it has classified, be these species, subspecies, or any other rank. A stable system of nomenclature is essential to communication about plants, and all botanical sciences have need to communicate about the subjects of their study. Taxonomists receive a certain amount of criticism under the general heading of "name changing," but the criticism generally comes from nontaxonomists who do not fully understand our present nomenclatural system or what the alternatives are. This is not the occasion for me to expound on botanical nomenclature, but I will simply say that the International Code of Botanical Nomenclature (1978) and the subsidiary International Code of Nomenclature of Cultivated Plants (1969) have been carefully crafted to promote nomenclatural stability, and they have been largely successful in doing so, as lucidly presented by Jeffrey (1973). The nomenclatural *in*stability that would result from alternatives to these codes would be chaotic in the extreme. So taxonomic research, in spite of the barbs of critics, is an important stabilizing influence on communication about plants in all disciplines of botanical science.

Perhaps the most profound influence that taxonomic research has on other kinds of agricultural and biological research is in making available sharpened perceptions of the limits of species or other taxa. Often what has been perceived as a single species, for example, has been found, after detailed taxonomic study, to be two or more species, and these constituent species are clearly distinct in geographical, ecological, or other pattern. One of the constituent species may provide a useful character or a scientific insight that had been overlooked or misunderstood as long as the species were confounded. In this manner taxonomy can lead the way, helping other agricultural and biological sciences to advance.

The problem of crop species

Crop plants are notoriously difficult subjects for taxonomic study as a result of their history of domestication and cultivation. They tend to be highly variable; to have both adapted and unadapted types preserved in cultivation; to exhibit intergrading, often in complex ways, as a result of hybridization; and sometimes to present reproductive anomalies, including apomixis and dependence on vegetative propagation. Additional complications arise from convergent evolution of crop species and closely related weed species, and escape and subsequent reestablishment of domesticated species in the wild. Geographical problems arise from the transport of cultivated plants to distant parts of the world by man, often in the distant past, or the accidental introduction of weeds to new areas. These things, which happen to some extent with all plants but to a greater degree with cultivated plants, complicate the patterns of variability and make it more difficult for the taxonomist to discover the order in the variability.

The taxonomist also needs to relate cultivated plants to their wild relatives, because only in this way can the nature and potential of the domesticates be fully appreciated. Moreover, the wild relatives are often a source of useful germplasm in plant improvement programs,

and a taxonomic understanding of them is a necessary preliminary step to their successful utilization.

The importance of germplasm collections

Obviously, germplasm collections provide taxonomists with a sampling of the variability characteristic of the plants in question, variability which it is their task to interpret. Germplasm collections are their raw material for study, their data base. But it goes beyond that. By cultivating plants in a uniform environment at a more or less convenient location, taxonomists can—

- explore relationships among the various accessions in the depth needed to elucidate the complex patterns of variability characteristic of the plants.
- make (or attempt) hybridizations.
- compare growth habits, photoperiodic response, disease response.
- enlist the collaboration of other specialists—pathologists, entomologists, phytochemists, cytogeneticists—to evaluate and obtain data on the collection, since their objective is to incorporate all classes of data into their studies and interpretations and not to rely too heavily on any one kind of data.
- preserve the available germplasm for the future so that it can be studied with techniques that have not yet been developed and help solve problems that have not yet arisen.

None of these things can be done as well by taxonomists working in the field, specifically, in the part of the world where the plants of interest have their center of variability. While plant exploration *is essential* to an understanding of the plants, and is the very means whereby germplasm collections are brought together, the comparative aspects of cultivation in a uniform environment cannot be studied in the field. Rather, field exploration and comparative cultivation are complementary and mutually supportive, the one to emphasize ecological position, geographical distribution, and involvement with man, the other to emphasize comparative biological properties, whether biochemical, morphological, or genetic. Germplasm collections are essential to the complete study of domesticated plants.

The role of herbaria

A word needs to be said about the role of the herbarium in taxonomic studies. It is important that field explorers who are gathering seeds and vegetative stock for living collections also collect voucher specimens of the plants they find. Herbarium specimens serve several purposes. In the first place, they constitute a permanent record, when deposited in an established herbarium, of the plant explorer's work. As germplasm curators know, living collections have a certain level of attrition; over the years some accessions will be lost, through inadvertent hybridization, through accident, through oversight, in spite of the best precautions. When some key living accession has been lost or contaminated by outbreeding, the herbarium voucher remains as a source of information about the plant.

Herbarium specimens play an important historical role also. Often it is possible to document the development of a new cultivar, or the introduction of a cultivar to a new part of the world, or the spread of a weedy species only from preserved and dated herbarium specimens. Voucher specimens preserved today help resolve questions for botanists tomorrow.

Herbarium specimens also have a less important but very practical value for the germplasm curator. I frequently get requests for seed samples from the cotton germplasm collection for which I am responsible that specify flower color, nature of leaf pubescence, or some other character that is desired. These things cannot be determined from examination of seed packets, and it may or may not be possible to find the information in field notes that are on file; but a glance at an herbarium specimen can resolve the question quickly. Preserved specimens are thus a useful record, more complete than most field notes can be.

But the most important role of an herbarium specimen is to serve as a voucher to document research. When a scientist has published a study on chromosome morphology or isozyme variability or whatever, it is important that voucher specimens of the plants studied be deposited in an herbarium (and cited in the publication), so that scientists of the future can verify the identity of the plant studied. It is surprising how often one hears the comment "I think the plant he *says* he studied was really such-and-such, misidentified." The only satisfactory way to resolve this doubt is to look at a voucher specimen.

So, germplasm collections provide a basic source of data for the taxonomic study of cultivated plants. The interpretations derived from such study can often be tested and extended by comparison with specimens preserved in the many herbaria of the world. This, too, is an important part of the study, because the specimens to be found in the herbarium, generally speaking, are the result of fieldwork by many collectors working over a wider geographic area and a longer time span than any individual collector is able to do. The taxonomic study of cultivated plants involves plant exploration, the study of preserved specimens, and the comparative study of living collections. The three are mutually supportive.

Two examples of productive taxonomic research based on germplasm collections illustrate some of the ideas presented here.

An example from *Chenopodium*

Chenopods are cultivated in the high Andes of South America at elevations of 2,500 to 4,000 meters and also in south-central Mexico at somewhat lower elevations. There are also weedy relatives in both North and South America that are considered as either progenitors or close relatives. Although the cultivated plants have several uses—as a grain (like wheat), as a vegetable (like broccoli), and as a green (like spinach)—and although they come from disjunct areas, they have long been considered to be a single species. This interpretation has proved to be a false assumption that has had implications both for plant

improvement programs and for the study of human prehistory and agricultural origins. In the one instance it has incorrectly implied the existence of a single germpool for plant breeders to draw upon; in the second it has implied evidently unwarranted prehistoric cultural contacts between two regions.

Detailed taxonomic study of this complex of cultivated and weedy chenopods, especially by D. C. Nelson, H. D. Wilson, and C. B. Heiser, Jr. (Wilson and Heiser 1979), has clearly shown that the Mexican cultivated species (*C. nuttalliae*) is closely related to the North American weed (*C. berlandieri*) but is clearly isolated from the South American cultivated species (*C. quinoa*). The latter, in turn, is closely related to a South American weedy species. So a drastically new interpretation has resulted from a taxonomic study of this group, based in large measure on 166 living accessions that constitute a germplasm collection of *Chenopodium*, and this new interpretation is having an important influence on agricultural research on this minor but potentially important crop plant.

An example from *Citrus*

The genus *Citrus* and related genera have proved to be very difficult subjects for taxonomic evaluation. Previous efforts to produce an objective classification of the various elements in the genus have been frustrated by such difficulties as widespread apomixis, diffusion around the world in cultivation far from their Asiatic origins, reestablishment in the wild in new localities, and an ability to hybridize easily. Such hybrids have been perpetuated freely in cultivation because of the attractive characteristics that many of them have. As a consequence, it has been essentially impossible to develop a meaningful species concept in this difficult genus or to bring any kind of satisfactory order to the classification of the group. Breeding work and other scientific studies of these important and interesting plants has consequently been impaired by the unsatisfactory nature of our taxonomic understanding of them.

A study by H. C. Barrett and A. M. Rhodes (1976), however, has brought to bear newer techniques of numerical analysis on this difficult genus. They have succeeded in discovering a pattern of variation and in giving it a taxonomic interpretation that makes sense. I venture to say that for the first time *Citrus* taxonomy has reached a level of understanding where it is meaningful and can be of service to other botanical sciences.

Barrett and Rhodes measured 146 characters on 43 "biotypes" of *Citrus* available in the germplasm collection. These data were used first to compute correlation coefficient matrices and then Euclidean distance matrices. The latter were the basis for ordination by a nonmetric multidimensional scaling technique. The details of their methods are not relevant here, but their conclusions are.

They found that certain plants were clearly distinct from all others—generally those that have conventionally been assigned to distinct genera other than *Citrus*, such as *Fortunella* and *Microcitrus*. This

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result was hardly anything new but was a good corroboration of earlier views and of the method. Of the plants assigned to *Citrus* proper, three groups were concluded to be "true biological species," *C. grandis* (pummelo), *C. medica* (citron), and *C. reticulata* (mandarin). The remainder are considered as "unique, apomictically perpetuated biotypes of probable hybrid origin." These include the various familiar oranges, lemons, limes, grapefruits, and other intermediate types, some of which are of known hybrid origin, and all of which have generally been assigned one of five different species names. This is a distinctly new taxonomic viewpoint, one that is clearly in accord with the available data, and one that will have a profound influence on future research with *Citrus*, primarily in providing a conceptual frame of reference concerning evolution in the genus, the constraints upon it, and the role that facultative apomixis has played in it. This knowledge, by extrapolation, applies as well to the future achievements of plant breeding, which is a form of directed evolution. The study was possible only because of the assembly and availability of the *Citrus* germpool, in this case a clonally propagated germpool.

The examples that I have chosen are simply two among many that might have been presented. But I believe they indicate some of the ways that taxonomic research and living collections interact to the mutual benefit of both.

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